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(71) Applicant(s)
LuK Getriebe-Systeme GmbH
(Incorporated in the Federal Republic of Germany)
Industriestrasse 3, 77815 Bühl, Baden,
Federal Republic of Germany

(72) Inventor(s)
Alfons Wagner
Jan Grabenstatter
Thomas Rammhofer
Michael Salecker

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(74) Agent and/or Address for Service
Dummett Copp
25 The Square, Martlesham Heath, IPSWICH, Suffolk, IP5 3SL, United Kingdom

(54) Abstract Title
Temperature compensating clutch control method

(57) An automatic clutch comprises an actuator 25, eg an electric motor, driving a crank drive 74 which operates a piston rod 72 of master piston 60. The master piston 60 contains a non-return valve 70 that allows hydraulic fluid to overflow from compensating chamber 62 into work chamber 58 of master cylinder 27. Movement of the master piston 60 is hydraulically transferred, via pipe 56, to slave piston 50 which extends to disengage the clutch and retracts, under an influence of a clutch spring, to engage the clutch. When engaging the clutch at low temperatures, eg -10°C to -20°C, the viscosity of the fluid prevents it moving quickly through pipe 56 so that under pressure occurs in the work chamber 58 which leads to an opening of the valve 70, thereby increasing the volume of fluid in chambers 52, 58. So that this increase in volume, eg pumping up, does not occur the speed of the electric motor 25 is altered, by an electronic controller, in dependence on the fluid temperature. For example, at low temperatures the speed of the motor 25 when engaging is slower than when disengaging, hence the retraction speed of the master piston 60 is matched to that of the fluid through pipe 56 so that no under pressure occurs and the valve 70 does not open. In another embodiment at low temperature a stroke of the piston 60 is controlled such that it passes snifting bore 64. The temperature maybe sensed, eg by temperature sensors in actuator 25, or it may be calculated. A method of checking the temperature sensors is also disclosed.

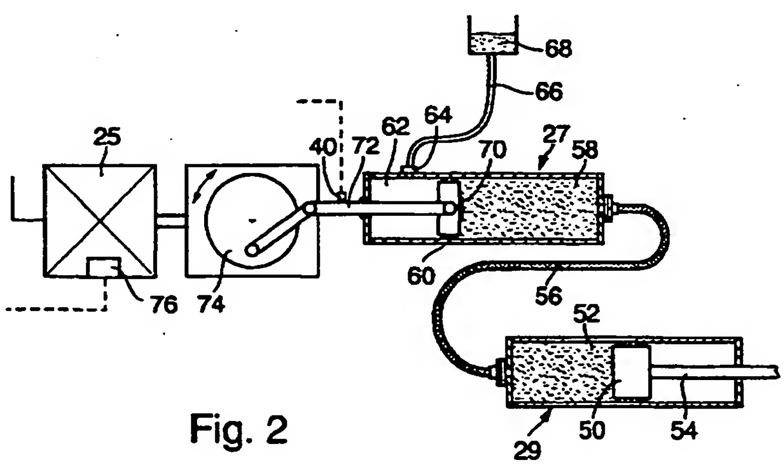

Fig. 2

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METHOD FOR OPERATING AN AUTOMATED CLUTCH
AS WELL AS FOR CHECKING A TEMPERATURE SENSOR

The invention relates to a method for operating an automated clutch in the drive train of a motor vehicle according to the preamble of claim 1. The invention further relates to a method for checking a temperature sensor inside an actor, more particularly a temperature sensor inside an actor, more particularly for an automated clutch.

The automation of clutches in motor vehicles hitherto operated by foot has become increasingly widespread. Clutches of this kind lead on the one hand to a considerable improvement in comfort. On the other hand they are absolutely necessary particularly in the case of automatic shift transmissions previously shifted by hand and lead there to the comfort of a vehicle equipped with conventional automatic gearboxes but without having their additional consumption.

In the operating transfer from a clutch actor, for example an electric motor, to the clutch itself there is generally a master cylinder whose master piston is operated by the actor, and a slave cylinder connected by a hydraulic line to the master cylinder and whose slave piston directly operates the clutch. At low temperatures the kinematic viscosity of the hydraulic fluid severely increases. When opening the clutch this would lead to increased pipeline pressures which with a very high output capacity of the actor or actors is linked with the danger that the hydraulic components would be damaged through unacceptably high pipeline pressures. Since however the output capacity of the actor is restricted, as the temperature decreases so the displacement speed drops whereby possible pressure rises lead to no overstrain on the components.

On closing the clutch the force of the clutch resetting spring must compensate pressure losses in the pipeline between master cylinder and slave cylinder. At low temperatures there is the danger that the pressure losses are no longer compensated by the resetting force whereby an underpressure occurs in the work chamber of the master cylinder which has the result that the hydraulic system consisting of both work chambers and the pipeline is pumped up which can lead to serious functioning errors.

The object of the invention is to provide a method for operating an automated clutch through which the problems at low temperatures as outlined above are reliably overcome.

The object of the invention is also to provide a method for checking a temperature sensor within an actor, more particularly for an automated clutch with which in a simple way it can be ascertained whether the temperature sensor is located in a satisfactory functioning state.

The part of the invention concerned with the clutch operating process is solved with the features of the main claim. By controlling the actor so that the excess pressure in the work chamber of the master cylinder remains present under all circumstances it is ensured that no pumping up of the system takes place. This can happen in that the resetting spring of the clutch is enlarged through additional measures .

It is advantageous according to claim 2 if the temperature of the hydraulic fluid is measured. Similarly according to claim 3 it is expedient if the temperature of the hydraulic fluid is calculated wherein the temperature of

the hydraulic fluid is calculated for example from the outside air temperature or this is set the same.

It is particularly advantageous according to claim 4 to reduce the speed of movement of the master piston at low temperatures. It can thereby be particularly expedient if the speed of movement of the master piston on reaching or understepping a boundary value of the temperature is reduced unidirectional. It is thereby particularly advantageous if at low temperatures the master piston is moved more quickly in the direction of reducing the size of the work chamber of the master cylinder than in the opposite direction.

With the feature of claim 5 it is reached that despite the reduced speed of the master piston in the closing direction of the clutch the clutch operating cycle remains overall as short as possible.

Claim 7 characterises a second solution of the invention. Each time if the master piston is moved over the snifting bore the system is pressureless so that with a following movement of the master piston in the opening direction of the clutch over the snifting bore, defined starting conditions are produced.

With the features of claim 8 a particularly high operating reliability of the clutch is achieved. Claim 9 characterises an advantageous method for determining the temperature of the hydraulic fluid for which no additional sensors are required whereby the temperature of the hydraulic fluid is used for controlling the clutch.

Claim 10 characterises the method for solving the second part of the inventive task. With this method the functional reliability of a temperature sensor can be

established inside an actor, for example the clutch actor, which is important for the operating reliability of the clutch, since temperatures which are too high inside the actor can signify faults inside the clutch and can lead to a breakdown of the actor.

With the features of claim 11 the reliability of the method according to claim 10 is improved further.

Claim 12 characterises a torque matching as a function of the temperature, that is the torque transferable by the clutch is determined in relation to the ensuing engine torque as a function of the temperature. Thus for example at high temperatures the torque transferable by the clutch is 1.05 times the engine torque and at low temperatures twice the engine torque.

The sub-claims 13 to 19 provide advantageous embodiments. Claim 20 relates to a method for the control or regulation of a device mentioned above.

The invention will now be explained below in detail by way of example and with reference to the diagrammatic illustrations in which:

Figure 1 shows a drive train of a motor vehicle with a block circuit diagram of the clutch control device;

Figure 2 is a detailed view of the arrangement according to Figure 1; and

Figures 3 to 5 are curves to explain the method of functioning of the method according to the invention.

According to Figure 1 a motor vehicle has a motor, such as an internal combustion engine 2 which is connected through

a clutch 4 to a gearbox such as shift transmission 6 which drives the rear wheels 12 through a Cardan shaft 8 and a differential 10. In order to brake the motor vehicle there is a brake unit 14 with a brake device 16 which is operated by a brake pedal 18. Only the connection between the brake device 16 and the left front wheel is shown. It is obvious that the brake device 16 interacts with all the wheels of the motor vehicle.

A drive pedal 19 which governs a throttle valve 21 serves to control the load of the internal combustion engine 2. The gearbox 6 is shifted by means of a shift lever 23. The clutched is automated and is activated by an operating unit such as by an actor 25 through a master cylinder 27 and a slave cylinder 29. The actor 25 is controlled by a control unit such as an electronic control device 31 which contains a micro processor with associated memories and whose inputs are connected to different sensors of the drive train for example a sensor 32 for the speed of the internal combustion engine 25, a sensor 34 for detecting the wheel speed of the vehicle, a sensor 36 for detecting a shift desire through operation of the gear lever 23, a sensor 38 for detecting the position of the clutch 4, a sensor 40 for the position of the actor 25, a sensor 42 for detecting the coolant water temperature, a sensor 44 for detecting the temperature of the intake air as well as where applicable further sensors. The device has a detecting unit for detecting a temperature. The temperature can be an outside air temperature, coolant temperature, intake air temperature or another temperature. A temperature can also be linked from data of another temperature with the aid of a mathematical model of the vehicle or of the thermal stretch between the areas of its temperature.

The slave cylinder 29 interacts directly with the clutch lever 48 which is forced by a clutch resetting spring (not shown) into its rest position in which the clutch 4 is completely closed, i.e. can transfer its maximum torque.

Figure 2 shows the component parts of the clutch activation in detailed illustration. A slave piston 50 works in the slave cylinder 29 and demarcates inside the slave cylinder 29 a work chamber 52. The slave piston 50 directly operates by means of its piston rod 54 the clutch lever 48 (Figure 1).

A pipeline 56 leads from the work chamber 52 into the work chamber 58 of the master cylinder 27 in which a master piston 60 operates which divides the master cylinder 27 into the work chamber 58 and a compensating chamber 62. In the cylinder wall of the master cylinder 27 a so-called snifting bore 64 is formed which is connected through a pipeline 66 to a hydraulic fluid container 68 which is ventilated towards the outside.

The master piston 60 has a valve member which forms together with it a non-return valve 70 which opens when the pressure in the compensating chamber 62 exceeds that in the work chamber 58. A crank drive 74 driven by the actor 25 formed as an electric motor serves to operate the piston rod 72 of the master piston 60.

The positioning of the arrangement is as follows:

The slave piston 50 is located on the left stop when the clutch is fully closed whereby the work chamber 52 is minimal and the master piston 60 is located directly in front of the snifting bore 64. When the master piston 60 is then moved further left by means of the actor 25 the non-return valve 70 opens so that the hydraulic fluid

overflows from the compensating chamber 62 into the work chamber 58. If the master piston 60 is moved further left beyond the snifting bore 64 then the work chamber 58 is connected directly to the hydraulic fluid container 68 and the system is reliably pressureless. If the master piston 60 is now moved to the right for opening the clutch then the pressure build up starts precisely in the position where the master piston 60 travels over the snifting bore 64 so that a defined starting position exists or association between master piston 60 and thus setting of the actor 25 and the fully closed position of the clutch 4. The master piston 60 is then moved so far to the right by means of the actor 25 until the clutch is completely opened. In order to close the clutch the master piston 60 need not necessarily be moved over the snifting bore 64 again if for example the clutch is deliberately not to transfer its full torque which is advantageous for many operating states. The slave piston 50 is then not moved into its stop position but rather the work chambers 58 and 52 also remain under pressure in the closed position of the clutch.

With very cold hydraulic fluid the situation can arise where on closing the clutch (moving the master piston 60 left by means of the actor 25) the then viscous hydraulic fluid does not flow quickly enough through the pipeline 56 so that an underpressure occurs in the work chamber 58 which leads to an opening of the non-return valve 70. The system volume (volume of the work chambers 52 and 58 including the volume of the pipe line 56) then increases so that the spatial association between the master piston 60 and slave piston 50 changes which is undesirable for reasons of operating accuracy. So that this pumping up does not happen with low temperatures the speed of movement of the master piston 60 in the closing direction of the clutch changes, as shown in Figure 3. S indicates

the path over which the master piston 60 has travelled, t indicates the time. An operating cycle is shown which starting from a closed clutch first opens the clutch (position 0). With high temperatures the ensuing closing movement (chain-dotted straight line 1) takes place at the same speed as the opening movement. As the temperatures become increasingly lower so the closing movement (straight lines 2 and 3) takes place with an increasingly slower speed. The result of this slower speed is that the hydraulic fluid can now flow quickly enough through the pipeline 56 so that no underpressure builds up in the work chamber 58.

Another solution for the problems encountered at low temperatures is shown in Figure 4. T represents the temperature, h the stroke about which the master piston 60 is moved starting from the position of the fully opened clutch. SB indicates the position of the snifting bore 64. As can be seen, the stroke at lower temperatures is always so that the snifting bore is passed so that with the next operating cycle defined starting conditions again prevail. At higher temperatures a smaller stroke can be travelled whereby it is possible to control the torque which the closed clutch transfers, according to the operating conditions. Depending on the prevailing temperatures or depending on the evaluation of the signals of the sensors 38 and 40 (Figure 1) a so-called snifting cycle can be travelled between the operating cycles of the clutch whereby the master piston 60 is moved deliberately through the snifting bore 64 so that the defined starting conditions for the clutch are again produced. As the temperature drops and the stroke increases (small torque adapting) the need is increased to install deliberate snifting cycles or when closing the clutch to move the master piston 60 beyond the snifting bore.

This is particularly advantageous when using a device for controlling the torque transferable by an automated clutch in the drive train of a motor vehicle having an engine and a gearbox with a shift element for selecting the gear transmission ratio and a sensor for detecting the gear transmission ratio, the engine has on the output side a controllable ensuing engine torque, with an operating unit such as actor, controllable by a control unit, for controlling the torque transferable by the clutch wherein the control unit controls the torque transferable by the clutch in dependence on the ensuing engine torque, with a device for detecting a temperature wherein the clutch torque is controlled within a predefinable tolerance band around the ensuing engine torque and the tolerance band is dependent on a temperature.

Thus overpressing the clutch can be increased at low temperatures compared to high temperatures. Torque matching as a function of the temperature, that is the torque transferable by the clutch in relation to the ensuing engine torque as a function of the temperature is particularly advantageous. It is for example expedient at high temperatures if the torque transferable by the clutch is for example 1.05 times the engine torque and at low temperatures is for example twice the engine torque. These numerical values are examples wherein at high temperatures a range of 1.02 to 1.5 is advantageous and at low temperatures a range of 1.5 to 2.5 is advantageous. The value for overpressing k, with $M_{kupplung} = k^* M_{motor}$ can rise as a function of the temperature. $M_{kupplung}$ and M_{motor} are the torque transferable by the clutch and the ensuing engine torque.

In another embodiment it can be expedient if below a boundary temperature the torque matching is switched off

and the torque transferable by the clutch is set to the maximum value, the clutch is thus fully engaged.

The temperatures from which the operating cycles of the clutch according to Figures 3 and/or 4 are necessary depend on the hydraulic fluid and the geometric conditions on the cylinders and the connecting pipe as well as the resetting force of the clutch and can be determined by experiment. In order to determine the temperature of the hydraulic fluid no special sensors are required if the temperature is determined according to the following algorithm:

$$T_{Fl,i+1} = k_{Mot} \text{ x } Dt \text{ x } T_{Mot} + k_{luft} Dt T_{Luft} + (1-k_{Mot} \text{ x } Dt+k_{luft} \text{ x } Dt) T_{fl,i}$$

wherein

Dt is time interval i, k_{Mot} and k_{luft} are empirically determined constants, T_{luft} and T_{mot} are each the mean values of the suction intake air temperature and engine temperature (approximated by the coolant temperature) during the relevant time interval i; $T_{Fl,i+1}$ is the fluid temperature at the end of the time interval i, and $T_{fl,i}$ is the fluid temperature at the start of the time interval i.

For the operating reliability of the automated clutch operation it is advantageous to know the temperature of the actor 25 which is generally formed as an electric motor. To this end the actor 25 is fitted with a temperature sensor 76 (Figure 2) whose output signal is evaluated by the control apparatus 31. To check the functional reliability of the temperature sensor 76 it is advantageous in the relevant possible operating situations, for example in neutral gear, to bias the actor by the control apparatus 31 with a signal sequence according to Figure 5a in which during a certain time duration, for example every 1 s long the piston rod 72 is

to be moved by a path of 15 mm which is ascertained by the sensor 40. The control apparatus regulates the current supplied to the actor 25 so that the ideal path shown is produced whereby the duration of movement amounts each time to about 150 ms. The activation of the actor 25 according to Figure 5a leads to an increase in the actor or actor temperatures according to Figure 5b. The temperature increase during the cycle according to Figure 5a is detected and evaluated in the control apparatus 31. If it lies outside of the plausibility limits entered by dotted lines in Figure 5b then a fault indication is carried out. It is obvious that the ideal temperature change (solid straight line according to Figure 5b) is determined empirically if it is ensured that the clutch is located overall in a satisfactory functioning state. To increase the reliability of the statement the current can be additionally detected which has to be supplied to the actor 25 so that the operating cycle is set according to Figure 5a. If the current pick-up deviates from the current pick-up determined when the clutch is in the satisfactory state then this points to a fault in the clutch system or in the actor.

The invention relates to a method for operating an automated clutch in the drive train of a motor vehicle and is characterised for example in that the actor is controlled so that even at low temperatures when the master piston is moved in the direction of increasing the work chamber in the master cylinder an excess pressure produced by the resetting spring of the clutch remains in the work chamber so that with this movement no hydraulic fluid overflows from the work chamber into the compensating chamber. With a further process the master piston is moved at lower temperatures after each clutch activation cycle beyond a snifting bore which connects the work chamber of the master cylinder to the fluid supply.

The invention further relates to a device for carrying out the above process.

At low temperatures the kinematic viscosity and thus the fluid friction of the fluid medium, such as a brake fluid, which is used as the hydraulic medium or fluid, increases severely. As the temperature decreases this leads in dependence on the master cylinder speed to an increase in the pressure losses.

OPENING OF THE CLUTCH:

During opening of the clutch pressure losses lead to increased pipeline pressures. If the output capacity of the actor were large then pipeline pressures of above 100 bar would damage the actor and the hydraulic components. Since however the output capacity of the actor is at lower values the actor speed and thus the pressure loss drops. The maximum pipeline pressures occurring are restricted for example to 40 bar. The pipeline pressures rising at low temperatures do not lead to an overload on the actor.

CLOSING OF THE CLUTCH:

When closing the clutch the resetting force of the clutch must compensate the drop in pressure in the pipeline. Below a fluid temperature of for example -15°C there is the danger than with maximum actor speed the pressure losses might no longer be able to be compensated by the resetting force. An underpressure is set at the master cylinder and the after-suction valve opens. If not snifted the system pumps up.

For an accurate temperature-dependent clutch control it is expedient if the fluid temperature is known. A simple

calculation model allows a calculation of the fluid temperature on the basis of existing temperature signals. At low fluid temperatures the kinematic viscosity of the brake fluid and thus the fluid friction increases sharply. This leads in dependence on the master cylinder speed to an increase in the pressure loss. In many embodiments a temperature-dependent clutch control is expedient because a water absorption of the brake fluid already from a fluid temperature of -15°C can lead to after-suction problems.

The following questions are dealt with: How great are the pressure drops in the pipeline and in the ZA (central disengagement member) in dependence on temperature, actor speed and water absorption? Does the danger exist that on opening the clutch the actor and hydraulic components are overloaded? From what temperature does after-suction occur on closing the clutch? Which measures are to be taken to prevent the hydraulic path pumping up? How can the fluid temperature be determined in dependence on known measuring signals?

1. PRESSURE DROP IN THE HYDRAULIC PATH

Since the Reynolds number in the hydraulic path is small there is a purely laminar flow. With a laminar flow the pressure drop Δp is a linear function of the mean flow speed v:

$$\boxed{\Delta p = c.v} \quad (1)$$

The following applies for the through flow resistance:

$$c = \frac{32\ell.\rho}{d^2}.\nu$$

wherein v is the kinematic viscosity of the brake fluid, ρ the density of the brake fluid, ℓ the pipeline length, d the pipeline diameter.

The hydraulic path is divided for example into two areas: The path outside of the gearbox bell consisting of two rubber hoses and a pipeline. The through flow resistance arising here is marked c_{Lei}.

The path inside the gearbox bell housing consisting of the pipeline and central disengagement member. The throughflow resistance is marked with C_{ZA}.

The through flow resistances (i.e. $\Delta p = c.v_{GZ}$) are listed in the following table:

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C_{Lei}	0,423	0,219	0,127	0,053	0,036	0,026
C_{ZA}	0,082	0,041	0,023	0,009	0,007	0,005

There is basically the following connection between the kinematic viscosity of the brake fluid and the fluid temperature T_{Fl} [°C]:

$$\nu = \frac{A}{(T_{Fl} + B)^n} \qquad \left[\frac{mm^2}{s}\right]$$

A, B and n are predefinable values.

If the brake fluid has absorbed q_w percent by weight of water then the factor $(1+q_w/C)$ is obtained. $1/C$ is a predefinable factor.

The fluid which is located inside the part of the hydraulic path lying in the gearbox bell housing is heated up more markedly than the fluid outside.

2. OPENING OF THE CLUTCH AT LOW TEMPERATURES

When opening the clutch the pressure rise which increases at low temperature as a result of increasing fluid friction loads the actor. Owing to the restricted output capacity of the actor the disengagement speed decreases (power output actor ~ master cylinder pressure . master cylinder speed). This is partially counteracted by the fact that at low temperatures the output capacity of the actor increases.

At the check state it was observed that the actor does indeed run more slowly but is not however switched off. Although the through flow resistance rises as the temperature falls the pressure losses are restricted as a result of the drop in the master cylinder speed ($\Delta p = c . v_{GZ}$).

3. CLOSING OF THE CLUTCH AT LOW TEMPERATURES

After-suction takes place for example at an underpressure on the master cylinder GZ of $p_{NS} = -0.025$ bar when the after-suction valve is opened. This master cylinder pressure is then understepped if the absolute resetting force of the clutch is no longer in the position of overcoming the pressure losses arising Δp.

When closing the clutch the absolute resetting force $F_{Rück}$ is composed of the disengagement force of the clutch F_{Kup}, the spring force of the spring in the central disengagement member ZA $F_{F,ZA}$ and the friction of the ZA F_{Reib} as follows:

$$F_{Rück} = F_{kup} - F_{F,ZA} - F_{Reib}$$

The resetting force builds up the following pressure at the ZA : $p_{ZA} = \frac{F_{Ruck}}{A_{ZA}}$ (3)

The pressure prevails at the GZ:

$$\boxed{p_{GZ} = p_{ZA} - \Delta p = p_{ZA} - c.v_{GZ}} \quad (4)$$

After-suction occurs at the place of the minimum master cylinder pressure $p_{GZ,Min}$.

As is apparent from (4) $p_{GZ,Min}$ hereby depends on the central disengagement pressure p_{ZA} and the master cylinder speed v_{GZ}.

After-suction occurs for example if the following applies: $p_{GZ,Min} = p_{NS}$

With C_{NS} there is obtained at (2) the fluid temperature from which after-suction occurs. The most critical case for the after-suction is that where the vehicle is cold (i.e. fluid temperature $T_{Fl} = T_{Lei} = T_{ZA}$).

$$\boxed{T_{Fl} = \sqrt[3]{\frac{a}{c_{NS}}\left(1 + \frac{q_w}{b}\right)} - c = -X°C}$$

Below a fluid temperature of for example X°C the system can be pumped up as a result of after suction. Basically there are two possibilities for avoiding pumping up:

The master cylinder speed is reduced when closing the clutch in dependence on the temperature so that no after-suction can occur.

The torque matching is switched off for example from X°C. The clutch is hereby completely closed after each shift process whereby the snifting bore is released and fluid compensation can take place.

Through known temperature signals it is possible to conclude or calculate the fluid temperature. The following temperatures which are relevant for fluid warming are available for example through a CAN data bus:

- Coolant water temperature $T_{Kühl}$
- Suction intake air temperature T_{An}
- Outside air temperature T_{Auss}

As already mentioned the hydraulic path can be divided into two temperature ranges:
Fluid temperature T_{Lei} outside the gearbox bell housing and fluid temperature T_{ZA} inside the gearbox bell housing wherein as a rule the following applies $T_{ZA} \geq T_{Lei}$

If it is assumed that T_{Lei} is the sole temperature prevailing in the system then one is on the safe side in respect of determining the temperatures which are critical for pumping up. The safety distance is hereby kept within limits since the pressure losses make up in the area of T_{ZA} only 15% of the overall pressure losses.

If the fluid and pipeline is heated up or cooled down then the heat stream between the fluid and atmosphere is proportional to the temperature gradient between the atmospheric temperature T_{Um} and fluid temperature T_{Fl} (fluid temperature and temperature of pipeline is practically the same):

$$\dot{Q} \sim (T_{Um} - T_{Fl})$$

The amount of heat given off or absorbed by the fluid depends on the mass and specific heat capacity of the fluid and pipeline:

$$\dot{T}_{Fl} = \frac{\dot{Q}}{m \cdot c_p} = k \cdot (T_{Um} - T_{Fl}) \qquad (k = \text{constant})$$

For a sufficiently small time interval $\Delta t = t_{i+1} - t_i$ this equation is simplified:

$$\frac{T_{Fl,i+1} - T_{Fl,i}}{\Delta t} = k \cdot (\overline{T}_{Um} - T_{Fl,i})$$

resp. $$\boxed{T_{Fl,i+1} = k \cdot \Delta t \cdot \overline{T}_{Um} + (1 - k \cdot \Delta t) \cdot T_{Fl,i}} \qquad (5)$$

whereby $\overline{T}_{Um} = (T_{Um,i+1} + T_{Um,i})/2$ is the mean atmospheric temperature in the time interval Δt.

Computer model:

The atmospheric temperature is concluded from the coolant water temperature, suction intake air temperature and external temperature.

The engine temperature T_{Mot} also has an effect on the fluid temperature as a warming part and the air temperature T_{Luft} (temperature of the air entering the engine chamber from the outside) has an effect as a cooling part.

ENGINE TEMPERATURE:

In the warm running phase (i.e. mean coolant water temperature $\overline{T}_{Kühl} > T_{Mot,i}$) the coolant water temperature rises relatively quickly. The heating of the engine block takes up very much more time. When the engine cools down (i.e. $\overline{T}_{Kühl} < T_{Mot,i}$) the cooling down speed of the coolant water corresponds approximately to that of the engine. For the mean engine temperature $\overline{T}_{Mot} = (T_{Mot,i+1} + T_{Mot,i})/2$ the following applies:

$$\overline{T}_{Kühl} > T_{Mot,i}: \qquad T_{Mot,i+1} = k_{Kühl} \cdot \Delta t \cdot \overline{T}_{Kühl} + (1 - k_{Kühl} \cdot \Delta t) \cdot T_{Mot,i}$$

$$\overline{T}_{Kühl} \leq T_{Mot,i}: \qquad T_{Mot,i+1} = T_{Mot,i}$$

AIR TEMPERATURE

By air temperature is meant the temperature of the air entering the engine chamber from outside. This temperature is as a rule the outside air temperature T_{Auss}, but can however also be the suction intake air temperature T_{An}. The following is to apply for the mean air temperature $\overline{T}_{Luft}$:

$$\overline{T}_{An} > \overline{T}_{Au\beta}: \quad \overline{T}_{Luft} = \overline{T}_{Au\beta} = (T_{Au\beta,i+1} + T_{Au\beta,i})/2$$

$$\overline{T}_{An} \leq \overline{T}_{Au\beta}: \quad \overline{T}_{Luft} = \overline{T}_{An} = (T_{An,i+1} + T_{An,i})/2$$

The temperature in the pipeline depends not only on the temperatures occurring but also on the air flow around the pipe line (thus on the vehicle speed, ventilation on/off).

With a slight circulating air flow: The measured outside air temperature is in this case slightly affected by the discharge heat from the engine (the lower the outside air temperature so the greater the influence). Since the

suction intake air temperature is in this case heavily influenced by the discharge heat from the engine, is $\overline{T}_{Luft} = \overline{T}_{An\beta}$.

The fluid temperature calculated thus rises with the temperature which is actually present.

With a severe circulating air flow: The measured outside air temperature corresponds to the actual temperature. The suction intake air temperature can even drop below the outside air temperature with a strong current, i.e. $\overline{T}_{Luft} = \overline{T}_{An}$. The calculated fluid temperature thus drops with that actually present.

In order to achieve a sufficiently good result with these temperatures with the lowest possible computer expense the following set-up can be provided:

$$\left(T_{Fl,i+1} - T_{Fl,i}\right) = \left(T_{Fl,Mot,i+1} - T_{Fl,i}\right) + \left(T_{Fl,Luft,i+1} - T_{Fl,i}\right) \qquad (6)$$

wherein $T_{Fl,Mot,i+1}$ is $T_{Fl,i+1}$ (see (5)) which arises when $\overline{T}_{Um} = \overline{T}_{Mot}$ wherein $k = k_{Mot}$
$T_{Fl,Luft,i+1}$ is $T_{Fl,i+1}$ (see 5)) which arises when $\overline{T}_{Um} = \overline{T}_{Luft}$ wherein $k = k_{Luft}$

(5) in (6):

$$\boxed{T_{Fl,i+1} = k_{Mot} \cdot \Delta t \cdot \overline{T}_{Mot} + k_{Luft} \cdot \Delta t \cdot \overline{T}_{Luft} + \left(1 - k_{Mot} \cdot \Delta t + k_{Luft} \cdot \Delta t\right) \cdot T_{Fl,i}}$$

For the k-values it is possible to set up as follows for example:

$$\boxed{\begin{array}{l} k_{Mot} = 10^{-4} 1/s \\ k_{Luft} = 30 \cdot 10^{-4} 1/s \end{array}}$$

It is sufficient to start the computer model when $T_{Auß}$ or T_{An} drops below -10°C.

Starting values:

$$T_{An} > T_{Anß}: \quad T_{Fl,1} = T_{Mot,1} = T_{Anß}$$

$$T_{An} \le T_{Anß}: \quad T_{Fl,1} = T_{Mot,1} = T_{An}$$

The computer model can be broken off for example when the ignition is switched off.

The present invention relates further to the earlier application DE 195 04 847 whose contents belong expressly to the disclosure of the present application.

The patent claims filed with the application are proposed wordings without prejudice for obtaining wider patent protection. The applicant retains the right to claim further features disclosed up until now only in the description and/or drawings.

References used in the sub-claims refer to further designs of the subject of the main claim through the features of each relevant sub-claim; they are not to be regarded as dispensing with obtaining an independent subject protection for the features of the sub-claims referred to.

The subjects of these sub-claims however also form independent inventions which have a design independent of the subjects of the preceding claims.

The invention is also not restricted to the embodiments of the description. Rather numerous amendments and modifications are possible within the scope of the invention, particularly those variations, elements and combinations and/or materials which are inventive for example through combination or modification of individual features or elements or process steps contained in the drawings and described in connection with the general description and embodiments and claims and which through combinable features lead to a new subject or to new process steps or sequence of process steps insofar as these refer to manufacturing, test and work processes.

CLAIMS

1. Method for operating an automated clutch in the drive train of a motor vehicle wherein an actor activates a master piston inside a master cylinder and the movement of the master piston is transferred hydraulically through a pipeline to a slave piston operating in a slave cylinder wherein the slave piston moves an operating member of the clutch against the force of a resetting spring in the opening direction of the clutch whereby the master piston contains a non-return valve which allows hydraulic fluid to overflow from a compensating chamber into the work chamber of the master cylinder, characterised in that the actor is controlled so that even at low temperatures during a movement of the master piston in the sense of increasing the work chamber in the master cylinder excess pressure produced by the resetting spring of the clutch remains in the work chamber so that during this movement no hydraulic fluid overflows from the work chamber into the compensating chamber.

2. Method according to claim 1 characterised in that the temperature of the hydraulic fluid is measured.

3. Method according to claim 1 characterised in that the temperature of the hydraulic fluid is calculated.

4. Method according to one of claims 1 to 3 characterised in that the speed of movement of the master piston is reduced at low temperatures.

5. Method according to claim 4 characterised in that low temperatures are temperatures below -10 degrees Celsius, preferably below -15 degrees Celsius and more particularly advantageously below -20 degrees Celsius.

6. Method according to one of claims 1 to 5 characterised in that at low temperatures the master piston is moved faster in the direction of reducing the size of the work chamber of the master cylinder than in the counter direction.

7. Method for operating an automated clutch in the drive train of a motor vehicle wherein an actor activates a master piston inside a master cylinder and the movement of the master piston is transferred hydraulically through a pipeline to a slave piston operating in a slave cylinder wherein the slave piston moves an operating member of the clutch against the force of a resetting spring in the opening direction of the clutch whereby the master piston contains a non-return valve which allows hydraulic fluid to overflow from a compensating chamber into the work chamber of the master cylinder and wherein a stop position of the slave piston corresponding to a minimal volume of the work chamber of the slave cylinder corresponds to the fully closed position of the clutch, the master piston can be moved by increasing the work chamber of the master cylinder through a snifting bore formed in the wall of the master cylinder and attached to a hydraulic fluid supply so that the work chambers are pressureless and the clutch is completely closed, and the master piston for controlling the maximum torque transferable by the clutch normally for closing the clutch is not moved over the snifting bore, characterised in that with a decreasing temperature of the hydraulic fluid and with an increasing number of closing positions of the clutch the master piston is moved over the snifting bore.

8. Method according to claim 7 characterised in that the a master piston at low temperatures is moved over the snifting bore after each clutch activation cycle.

9. Method according to claims 1 to 8 characterised in that the engine temperature T_{Mot} and the external air temperature T_{Luft} are measured, the temperature of the hydraulic fluid T_{Fl} is calculated according to the following algorithm:

$$T_{Fl,i+1} = k_{Mot} \times Dt \times T_{Mot\_mittel} + k_{luft} \times Dt \times T_{Luft\_mittel} + (1-k_{Mot} \times Dt + k_{luft} \times Dt)T_{fl,i}$$

wherein
Dt is time interval i,
K_{Mot} and k_{luft} are empirically determined constants,
T_{luft_mittel} and T_{mot_mittel} are each the mean values during time interval i;
$T_{Fl,i+1}$ is the fluid temperature at the end of the time interval i,
$T_{fl,i}$ is the fluid temperature at the start of the time interval i, and
the operation of the clutch is controlled in dependence on the calculated temperature $T_{fl,i+1}$.

10. Method for checking a temperature sensor inside an actor, more particularly for an automated clutch wherein the actor inside a test cycle in a predetermined time sequence by biasing with regulated current displaces a transfer member over predetermined paths and the temperature test curve measured by the temperature sensor during the test cycle is compared with a temperature ideal curve which was measured in the same test cycle in the case of a temperature sensor located in a satisfactory state wherein any deviation extending beyond a certain amount between the temperature test curve and the temperature ideal curve is evaluated as a reference to a faulty state of the temperature sensor.

11. Method according to claim 10 characterised in that in addition the current taken up by the actor is checked and compared with the current taken up in the temperature ideal curve.

12. Device for controlling the torque transferable by an automated clutch in the drive train of a motor vehicle with an engine and a gearbox, the motor has on the output side a controllable arising engine torque , with an operating unit, such as actor, controllable by a control unit for controlling the torque transferable by the clutch, with a device for detecting the temperature, characterised in that the control unit controls the torque transferable by the clutch in dependence on the ensuing engine torque whereby the clutch torque is controlled inside a predeterminable tolerance band around the ensuing engine torque and the tolerance band is dependent on the temperature.

13. Device according to claim 12 characterised in that the width of the tolerance band is temperature-dependent.

14. Device according to claim 12 characterised in that the torque transferable by the clutch is proportional to the engine torque through a proportionality factor and/or a summand.

15. Device according to claim 12 characterised in that the torque transferable by the clutch is greater by a predeterminable amount than the ensuing engine torque.

16. Device according to claim 12 characterised in that the tolerance band in a higher gear is greater than or the same as in a lower gear.

17. Device according to one of claims 14 characterised in that the proportionality factor and/or the summand is greater or the same at higher temperatures than at lower temperatures.

18. Device according to one of the preceding claims characterised in that the transferable torque at low temperatures is in the range from 1.5 and 2.5 times the ensuing engine torque.

19. Device more particularly according to one of the preceding claims characterised in that the maximum rise per unit time of the torque transferable by the clutch is selected as a function of the temperature.

20. Method for the control or regulation of the torque transferable by the automated clutch more particularly by means of a device according to one of the preceding claims 12 to 19.

21. Method for operating an automated clutch in the drive train of a motor vehicle substantially as herein described with reference to the accompanying drawings.

22. Device for controlling the torque transferable by an automated clutch in the drive train of a motor vehicle substantially as herein described with reference to the accompanying drawings.

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Application No: GB 9811740.1 **Examiner:** Mike McKinney
Claims searched: 1 to 6, 9 and 18 to 20 **Date of search:** 7 January 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): F2L (LK).

Int Cl (Ed.6): F16D 25/08, 25/12, 27/00, 29/00, 48/02, 48/04, 48/06.

Other: ONLINE: WPI; EDOC; JAPIO.

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X; P	GB 2317933 A (LUK) see figs and lines 20 to 29 page 22.	1.

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		

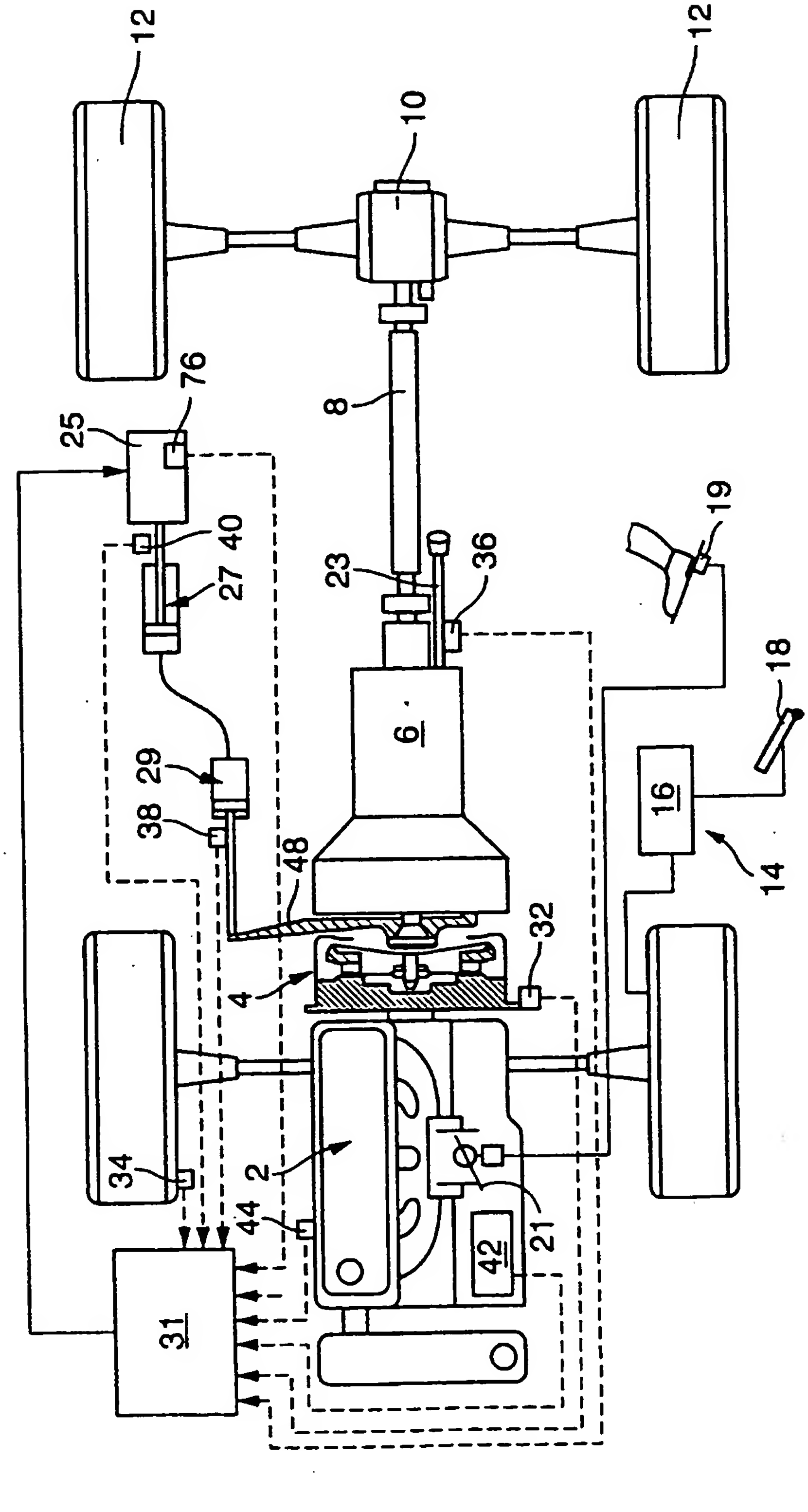

Fig. 1

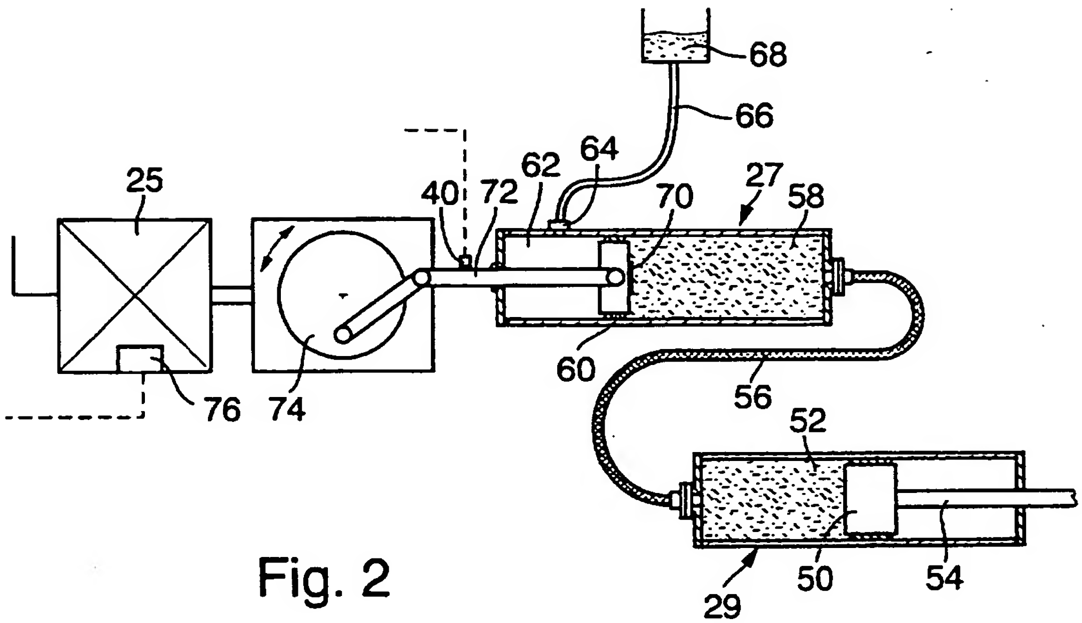

Fig. 2

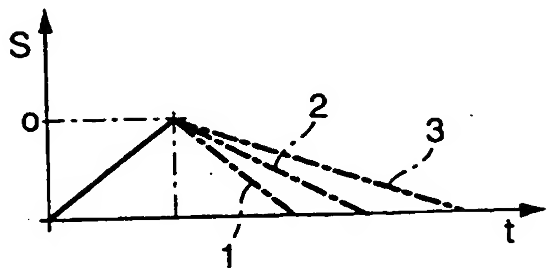

Fig. 3

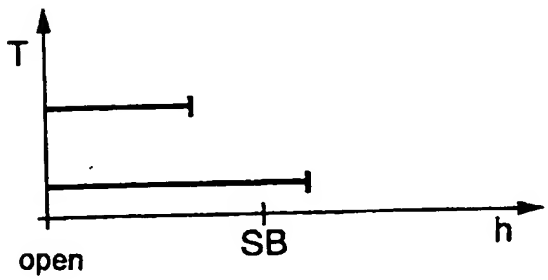

Fig. 4

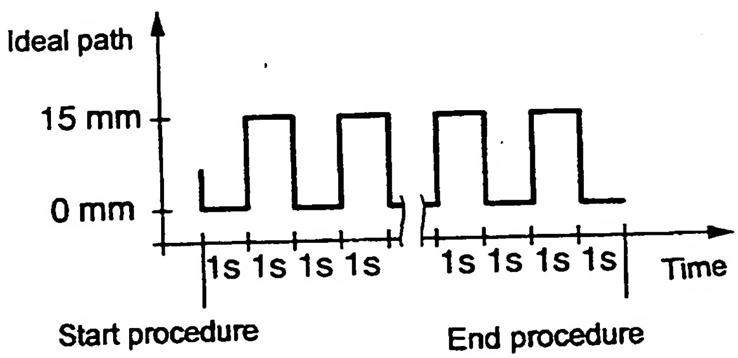

Fig. 5a

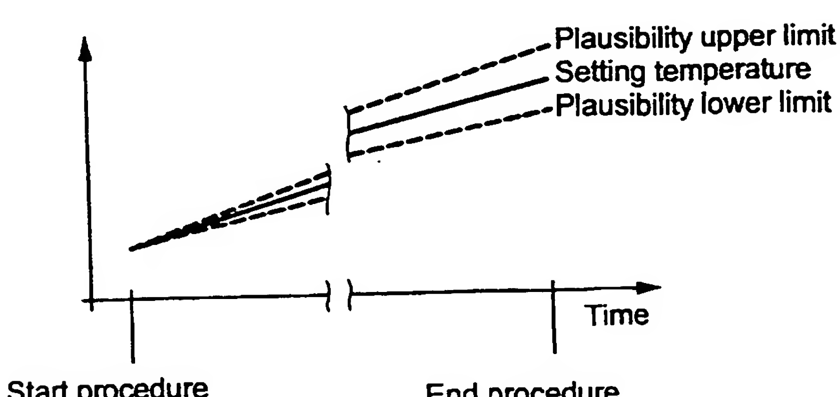

Fig. 5b